Joint-Rollout of FTTH and Smart City Fiber Networks As a Way To Reduce Rollout Cost

Jonathan Spruytte[1]* , Frederic Vannieuwenborg[1], Kurt Marlein[2], Gustav Janssens[2], Raf Meersman[2], Sofie Verbrugge[1], Didier Colle[1]

1 IDLab, Department of Information Technology at Ghent University – imec,
Technologiepark-Zwijnaarde 126,
9052 Gent, Belgium
{firstname.lastname@ugent.be}

2 Comsof,
Sassevaartstraat 46/214,
9000 Gent, Belgium
{firstname.lastname@comsof.com)

***Abstract*— Making cities smarter is the future. By bringing more technology into existing city infrastructure, smart city applications can arise. Whether these applications track devices e.g. public lightning, environmental measurements e.g. temperature or air quality, or analyze video streams e.g. for people density, it is expected that these will require a (near-) real time data connection. Upcoming 5G networks will be able to handle large amounts of connections at high speeds and low latencies and will therefor outperform current technologies such as 4G and low-power wide-area networks. In order to do so, these 5G networks fall back to numerous fiber connected small cells for up & downlink to the Internet. In this publication, we are looking into the additional fiber equipment and deployment cost to connect the required smart city network infrastructure, taking into account a Fiber-to-the-Home (FTTH) network is already available or will be installed as part of the smart city network rollout. More concretely, we are proposing a methodology comparing an anticipated and incremental planning approach for a number of different extensions upon the FTTH-network: connecting all electrical cabinets, connecting public lightning, and the connection of 5G using small cells. From this, we want to learn how much the total rollout cost can be reduced using a future-oriented smart city approach taking into account all future extensions, compared to an incremental short-time planning only planning additional fiber when required. In the meantime, we want to show the additional cost of creating a smart city network is limited when it is being combined with a FTTH rollout. Results of the proposed methodology and use case will be modeled planning and design software Comsof Fiber and will be published in a future work.**

Keywords—FTTH, smart cities, network planning, techno-economics

I. Introduction

Smart cities are *the* future, whether we talk about waste bins that provide alerts when nearly full, air quality measurements or cameras to measure crowd moments and density, in either case a connection with the municipal communication network and/or the Internet is required [1]. For some services, e.g. air quality measurements, periodic (non-real) time measurements suffice, requiring only very little data throughput. This kind of services often use battery-powered sensory devices and rely on Low Power Local Area Networks (LPWAN) for their uplink to the Internet [2]. Other services, e.g. services that rely on real time camera images cannot use these technologies due to various bandwidth restrictions. These services can fall back to wireless technologies such as cellular networks (e.g. 4G and the upcoming 5G standard) or can directly be connected upon a cabled network (e.g. xDSL, DOCSIS 3.0/3.1 or fiber). With the ever growing increase for more and faster data connection, current cabled technologies (xDSL and DOCSIS 3.0/3.1) cannot keep up with fiber networks over longer distances; in some countries these copper networks are already gradually being shut down (referred to as copper switch off) [3]. As a result, a global trend can be seen to fiber or hybrid-fiber networks [4]. It is expected that in the future, fiber will be the most relevant cabled data communication network which will also connect 5G networks to the Internet forming so called converged fiber networks [5],[6].

The cost of rolling out a new cabled network should not be underestimated, the cost per home passed ranges from approximately 500 euro (dense urban) up to and above 2000 (rural) [7],[8]. As shown in Figure 1, a more dense connection count results in a lower cost per home (or demand point [1] in general) passed. As a result, when additional demand points can be connected in a city environment (e.g. electrical cabinets) the additional costs of these extra connections can be considered small. When different fiber networks were to be installed e.g. one for homes and one for electrical cabinets, the cost difference is expected to be larger as demand point density differs greatly as visualized in Figure 2.

[1] In this publication, the generic term *demand point* is used for any physical location requiring a connection with the fiber network.

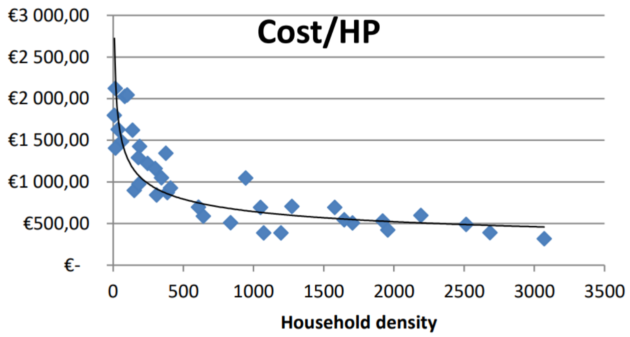

Figure 1: Cost per home passed in relation to the household density (households/km2) shows a strong decrease cost with increased density [7].

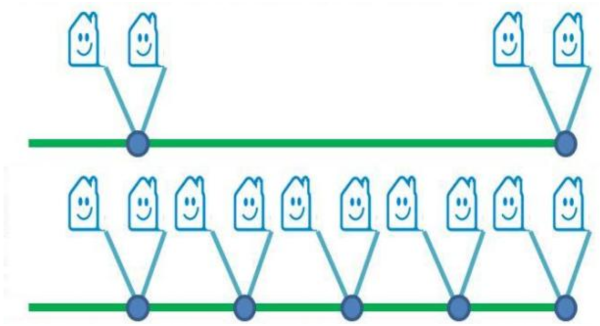

Figure 2: As a result of a higher connection density, the cost of ducts is shared amongst more homes passed, resulting in a lower cost per home passed, based on [7].

As a result, a well-defined future-oriented planning taking into account all demand points that may require a fiber connection—either immediately or in the future—may reduce the overall cost.

The goal of this publication is the introduction of the used approach and suggested scenarios which are part of an ongoing study; the actual results of the scenarios are still being simulated and are thus beyond the scope of this publication.

The remainder of this publication is as following. In section II we introduce the main goals of this study and the two main modeling components. Section III introduces the use case and the different scenarios at hand. Finally scenario IV introduces what lessons we hope to learn from the future results.

II. GOAL OF THIS STUDY

The goal of this study is to look into the additional cost of fiber enabled smart city networks taking into account a Fiber-to-the-Home (FTTH) network and fiber connected 5G cells are being installed as well. More exactly, we look into how the additional costs differ if a smart future-oriented (anticipated) planning is being applied taking into account the smart city network, FTTH and 5G compared to a short-term incremental planning. In order to do so, we apply two main modeling steps: a) modeling the required location of 5G base stations and b) modeling the required fiber equipment and connections to connect different demand points in the city environment (homes, electrical cabinets, gas cabinets, 5G base stations).

These modeling steps are applied for a number of scenarios (discussed in section III) in combination with two variations of the design rules (e.g. the number of spare fibers and ducts that are being installed). In this publication, we only look into the cost of the required passive equipment of the fiber installation and the cost of installation.

A. 5G modeling

In order to perform the fiber modeling, all demand points have to be known. While the homes, electrical and gas cabinets are provided and fixed, this is not the case for the location of the base station of the 5G network.

The 5G access is assumed to be delivered from two layers via the 3.5 GHz and 26 GHz frequency bands. The 3.5 GHz base stations are installed on existing 4G macro-cellular sites, although we assume no fibers are available or can be used and thus a new demand point is introduced. The 26 GHz small-cells are positioned inside some buildings of particular interest, with poor macro coverage quality but with high data traffic e.g. in train stations. They can also deployed be on lampposts in order to offer high data rate services in the streets and public squares. The 26 GHz small-cells have much smaller coverage radius compared to the 3.5 GHz macro-cells, but allow to significantly increase the network capacity thanks to additional spectrum resources and dense frequency re-use.

The 5G network coverage is simulated from the deterministic propagation model Volcano, which is computing the *canyoning* effect from multiple reflections and diffractions on the building facades.[9] Some margins are added to the radio link budget to account for various losses and local shadow fading. Finally, the 3.5 GHz macro-cell layer is required to cover the whole outdoor area, but only 70% of the indoor coverage. The small-cell layer is designed from an Automated Cell Planning (ACP) tool with an outdoor coverage target of 95%. The technical design parameters that are being used are discussed in section III.B.

B. Fiber modeling

For the modeling of the required fiber connections we fall back to the commercial *Comsof Fiber* tool which is a fiber network planning solution for both Passive Optical Networks (PON) as well as Point to Point (P2P) networks. The tool takes into account the costs for civil work, material and labor and calculates the required FTTx network topology based upon a variety of input parameters: the geographical location of the demand points, the availability of existing infrastructure (e.g. aerials routes, existing ducts), the cost per route (i.e. digging a new duct will be more expensive than a facade connection) and which equipment is available (type of cables, ducts, manholes, cabinets) and at which price. Using this input and a set of design rules (e.g. the number of spare fibers and ducts that are being installed) the tool calculates the entire fiber topology and its accompanying Bill of Materials (BOM).

III. Application of the Models to Multiple Scenarios

The discussed model will be applied for a selected region in the city of Ghent (see Figure 3). In the area (which measures approximately 3.5km^2), following demand points are present:

- ~24 000 homes
- ~240 electrical cabinets (to create a so-called smart grid, SG)
- ~3 500 public lightning poles (PL), as a way to create a dense smart cities network for the future to be able to support sensory networks
- 5G base stations using the 3.5Ghz frequency range for the entire area and small cells using 26Ghz for three indicated hotspots

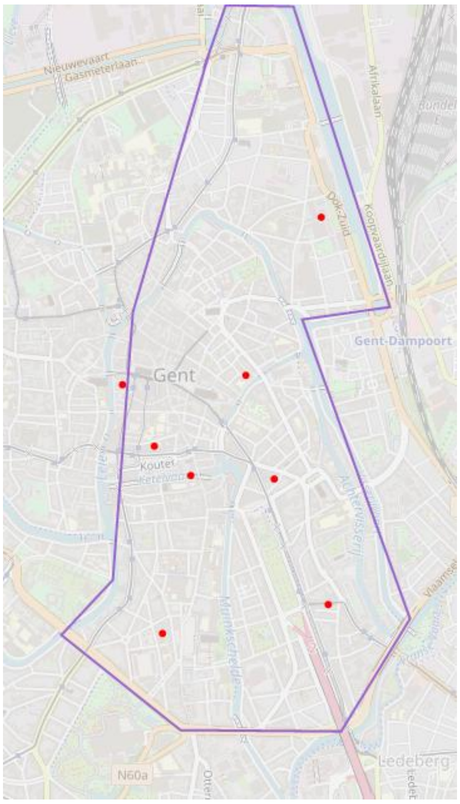

Figure 3: Area of the city of Ghent to which the different scenarios are being applied.

A total of eighteen scenarios will be calculated connecting different subsets of the demand points in the city of Ghent. These eighteen scenarios are divided in two sets of nine. The nine different scenarios differ depending for which demand points fiber will be installed and whether an anticipated planned or incremental planning will be used, as introduced next in section A. The differences between the two sets are different design rules that are being applied for the fiber rollout, as introduced later in section B.

In the scope of this publication, an anticipated planning means different demand points are *planned* at the same time, allowing for an optimization for all demand points. This however does not mean all connections have to be rolled out at the same time.

Using an incremental planning, demand points are added, planned and rolled out using incremental steps. Using this approach there is no long-term view of how the network will evolve which leads to a less optimized, more costly network.

A. Nine scenarios

As said a total of nine scenarios are being planned, consisting of the connection of different demand points:

1: **FTTH**: Deploying fiber to all homes passed and every entity of multi-dwelling units (FTTH)

2: **FTTH + Smart Grid (SG):** Next to the homes and multi-dwelling units, additionally 20% of the electrical cabinets will be deployed with fiber to provide real-time monitoring. Due to the small number of additional fibers to connect these cabinets, it can be expected this will only differ marginally from the first scenario.

The second scenario is considered the reference scenario to which the other scenarios will be compared to. The remaining seven scenarios are divided in two groups: incremental and anticipated planning.

3 to 6: **incrementally** adding public lightning and 5G in different orders to the second reference scenario.

7 to 9: **anticipated** planning of the second reference scenario combined with either PL or 5G, and with the both PL and 5G.

The different scenarios are visualized in Figure 4. Demand points which are planned together are joined in a single rectangle (anticipated planning); multiple rectangles represent an incremental planning.

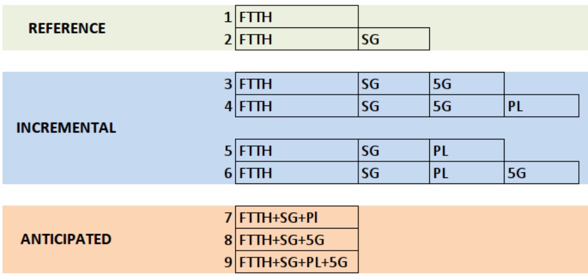

Figure 4: Visualization of the nine different scenarios, divided in reference, incremental and anticipated; these are simulated twice for either set of design rules.

For both the fiber modeling and 5G network some design rules and technical parameters are being considered which are discussed next.

B. Design rules for fiber and 5G network

The highest level considered in the fiber network is a Point of Presence (POP) a so called demarcation point which connects the access network (which provides the *last-mile* connection to the demand points) with the network of the Internet Service Provider. From the POP only P2P (Point to Point) connections run to demand points via distribution points and drop boxes as shown in Figure 5.

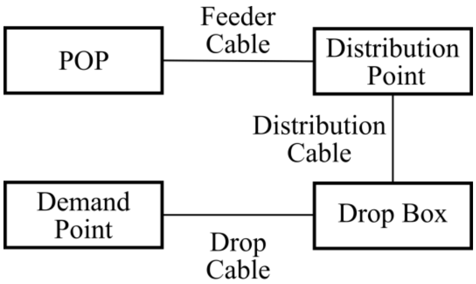

Figure 5: High level overview of the different structural elements of the fiber topology considered.

A POP serves a predetermined area and connects to multiple Distribution Points (DP) which are connected using *shared*, underground, *feeder* cables with a fiber count of 96, 192 or 288. The term shared cable refers to the fact that a single feeder cable can connect multiple DPs and is thus shared. As a result a feeder cable can contain branches.
When dimensioning, up to 160 fibers are connected to a single DP. DPs are basically locations in which the P2P connections are further split up towards different drop boxes via so called *distribution cables*. These have various sizes (fiber counts of 48 and 96) and can be installed either underground or aerial.
Lastly, from the drop boxes (also called drop points), *drop cables* run to the actual demand points. A drop point typically services four buildings either Single Dwelling Unit (SDU) or Multi Dwelling Units (MDU). The fiber count of the cables is adjusted to the total number of living units to be connected.
On the cables running between POP and DP and between DP and drop points, additional spare capacity can be provided, mean additional fibers in the *feeder* cables and in the *distribution* cables and capacity in the DP. In this study we consider two variations: 0% and 20%. In either case we consider sufficient empty ducts are installed to support additional fibers in a later stage. No spare capacity is considered for the drop cables connecting the demand points. In all scenarios, we connect each home and unit of a multi-dwelling unit (MDU) with *two* fibers, 3.5Ghz base stations with multiple fibers in function of number of expected users and any other demand point with just a single fiber. A summary of the most important parameters considered in the modeling is provided in Table 1.

Table 1: Technical parameters for the fiber modeling.

Parameter	Value
Spare fiber per cable	
• **Feeder**	0 / 20%
• **Distribution**	0 / 20%
• **Drop**	0%
Cable over length (spare length as an error margin and cable sag)	3% for underground 10% for aerial
Fiber per demand point	2 per living unit Multiple for 3.5Ghz base stations 1 for other demand points
Max cable length	
• **Feeder Cable**	-
• **Distribution Cable**	500m
• **Drop Cable**	100m
• **Total**	1000m
Fiber count per cable[2]	
• **Feeder**	96,192,288 (U)
• **Distribution**	48, 96 (U/A)
• **Drop**	2, 48 (U/A), 96 (U)

The most relevant parameters which will be used for the 5G modeling are listed in Table 2 and will be used in the earlier mentioned Volcano model [9].

Table 2: Technical parameters for the 5G network simulation

Parameter	Value
Base station transit power (downlink)	40dBm (@3.5GHz) 30dBm (@26GHz)
Bandwidth	80MHz (@3.5GHz)
Beamforming antenna gain	23dBi (@3.5GHz) 20dBi (@26GHz)
User terminal antenna gain	5dBi (@3.5GHz) 9dBi (@26GHz)
Noise figure	9dB

IV. EXPECTED OUTCOME AND INTENDED RESULTS

As stated in the introduction, the goal of this study is to look into the additional cost of a smart cities network on top of a FTTH-network under different conditions (design rules) and planning approaches.

		Planning approach	
		Incremental	**Anticipated**
Spare capacity	**Few spares**	Highest	Lowest
	A lot of spares	High	Low

Figure 6: Expected costs for different deployment scenarios

From the different scenarios we expect to be able to make following high level conclusions:

- An anticipated planning should result in a cheaper end-result as a result of a more future-oriented approach.
- Installing more spare capacity in case of an incremental planning will increase the initial cost, but may reduce the total cost as the initially spare capacity is used in later stages. Installing more spare capacity in case of an anticipated planning will result in having empty fiber after the planned installation and will thus keep room for future, still unknown, upgrades. This however will come at a higher cost than only planning for the exact needs at this moment (meaning few spares), this is the cost of being future-minded.

Additionally, we expect to be able to clearly compare the different scenarios and indicate the additional cost of both 5G and a smart cities network is limited on top of a FTTH network especially in case of an anticipated planning approach.
The modeling of the different scenarios as discussed in the publication is currently ongoing and will be discussed in a future publication.

[2] U=Underground, A: Aerial

V. ACKNOWLEDGEMENTS

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